Chapter 32
The Application of CIM and BIM to the Simulation of Energy in Urban Superblocks; an Effort to Develop the Initial Digital Twins (Case Studies: Kermanshah, Iran)

Omid Veisi and **Amir Shakibamanesh**

Abstract The integration of Building Information Modelling (BIM) and Geographic Information System (GIS) and the suggested notion of digital twins enabled buildings to be energy-efficient in terms of consumption and generation. The study employs a real-world simulation with a low level of detail to examine several types of urban superblocks and their energy use. This research presents a unique approach for integrating urban information based on two-dimensional GIS data and a three-dimensional BIM model. The research approach used in this study is a comparison of the types of urban blocks and energy, which is considered for early energy studies instead of optimising the urban configuration. Several archetypes of blocks were modelled, analysed and then studied on three levels: electrical energy, fossil fuel and energy. The study's conclusion implies that optimisation techniques can be used in the comparative approach. While studying these various methods consumes a significant amount of time and energy, archetype evaluation consumes far less. Finally, the results reveal significant reductions in energy use in urban buildings of up to 20% compared to the ASHRAE standard model with a modest degree of detail. The results of this research may be used in the early stages of urban design in terms of superblock pattern selection.

Keywords Energy efficiency · City Information Modelling · Building Information Modelling · Archetype · Urban super-block · Digital twins

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Introduction

Globally, increased population and urbanisation-related constraints need new construction and the establishment of dense metropolitan areas. However, the engineer does not develop these future urban centres using Urban Energy Building Modelling tools. Numerous studies have been conducted to create new ways for modelling high-performance buildings (Arabi et al. 2022) with the least impact on the environment and the maximum level of spatial comfort at the lowest cost (Shafiei et al. 2020). Except for study and modelling, it is currently impossible to apply these methodologies to Urban Energy Building Modelling (UBEM) and proposal design for soaked structures and microclimate complexes. That is why simulation technologies are critical for guiding urban planning and optimising the environmental efficiency of buildings. Implementing simulation tools and developing master plan ideas in cities are a novel part of engineering and applied sciences which have given little attention to it in recent studies (Dogan 2015).

This broad notion resulted in developing new approaches like BIM, GIS, City Information Modelling (CIM) and software-based studies. Numerous researchers assert that legacy software and methods are unsuitable for real-time data collection and analysis, particularly when urban planners, urban designers and architects wish to explore and design for a specific city area and require a three-dimensional form with varying levels of detail (LOD) (van Treeck and Rank 2007; Pratt et al. 2012). These difficulties affect the construction of instruments based on three-dimensional dimensions, the technique for collecting data in urban development, the analysis used in planning, designing and construction and the respect for people's privacy.

Additionally, using advanced technology, simulations for the urban building's lowest level of detail may be accomplished quickly. On the other hand, simulating urban models might take days, even with parallel or cloud computing capabilities available. The different variables related to urban buildings are likewise inaccessible to modellers and architectural engineers for two reasons: first, time and objective simulation and second, mass UEBM (Cerezo Davila 2017). The method of this study uses comparison methods and simulation based on real context. The GIS is used for mapping, and the BIM is used for adding height dimensions. So, the main purpose of this study focuses on the comparison between archtype of superblock based on the energy consumption in the shortest time for urban planners. So, to achieve this aim, the research should be answered this question, how can calculating different type of energy by the lowest information in order to choose the best type of archetype of the urban block?

Aims and Originality

Nowadays, different types of energy analysis are used by engineers in various industries including urban planning, urban designer and architecture. Also, the most practical energy analysis model is utilised by academics and businesses. This method has been widely used in architectural research, notably for optimising shape to reduce energy consumption in interior areas (Omid et al. 2022). Based on a review of the scientific literature and the observed gap, more research is required on these techniques. Using the capabilities of City Information Modelling (CIM) and Building Information Modelling (BIM), it seems that speed of discovering optimal solutions and accuracy of optimal solutions may replace traditional techniques in industries and technological issues. In the early phases of urban design, reducing the computation time and enhancing the precision of calculating the ideal solution may be very useful and practical for optimising the performance of urban superblocks. The purpose of this study is to analyse and assess the ability of BIM and CIM to improve the optimisation performance of various urban superblocks, taking energy usage and degree of detail into account (LOD). This chapter presents a simple, optimal and high-precision solution for optimising multi-objective urban issues using novel techniques. Designers and engineers in different city sections are recommended to interact more during the early stages of urban block form optimisation in light of the aforementioned advantages and possibilities. This article seeks to go ahead in comparison to prior studies in the area of urban superblock design and propose an appropriate answer for the study gaps described in the previous section, based on the need that its research process has produced.

Due to the many elements in this subject, a substantial amount of time and work is required to optimise the models in this research. This realisation seeks to identify the optimal urban superblock without spending time and research costs by gathering complete data. Planners may examine the form of an urban superblock in terms of its energy usage over the shortest amount of time. The result of the initial investigation into the various forms of urban superblocks was the identification of six distinct types. An analysis of energy consumption will be conducted to expand the various types of urban superblocks with different factors and predict their energy consumption as a result. This data collection may be enhanced and extended by other researchers in order to increase the accuracy and capacity of energy consumption prediction for the different types of urban superblocks. Researchers and designers will no longer need to depend on other computational tools for model optimisation if they can calculate the amount of energy consumption at urban superblocks.

In addition to bolstering the CIM model with BIM models by combining these two methodologies, more beneficial responses may be discovered in the research-relevant study area. From the standpoint of urban design and planning, every study on urban spaces reveals that the kind of urban blocks and the researched area have a substantial effect on energy consumption (Shakibamanesh and Veisi 2021b; Veisi and Shakibamanesh 2022; Omid et al. 2022). Additionally, urban areas with a certain form of urban superblock have a dramatically lower energy use. This disregard for maximising the design of urban blocks is shown by little research on urban blocks and by this study's review of the relevant literature (Li et al. 2022). In this regard, the current research tries to find the optimal design options for common urban superblock types in terms of energy consumption efficiency.

Abbreviation	Description	Abbreviation	Description
BIM	Building Information Modelling	GIS	Geographic Information System
CIM	City Information Modelling	IFC	International Finance Corporation
UEBM	Urban Energy Building Modelling	PCA	Principal Component Analysis
EBM	Energy Building Modelling	PTC	Percentage of Thermal Comfort
EUI	Energy Use Intensity	UE	Urban Engineering
CVRMSE	Coefficient Variation Root Mean Square Error	TC	Thermal Comfort
HVAC	Heating, Ventilation and Air Conditioning	BA	Building Area
LOD	Level of Detail	DS	Design Space
DVS	Design Variables	USB	Urban Superblock
OSM	Open Street Map	LiDAR	Light Detection And Ranging
NMBE	Normalised Mean Bias Error	IoT	Internet of Things

Interaction Between CIM and BIM

Researchers have created new approaches for modelling digital cities in the twenty-first century, including CIM (Stojanovski 2013), BIM (Xu et al. 2014), Light Detection And Ranging (LiDAR) (Verma et al. 2006), CityGML as a conceptual model and exchange format for the representation (Kolbe et al. 2005). The City Information Modelling, as the most current technique based on BIM and GIS, has several disadvantages, including a lack of optimal software to generate practical output. Although a substantial percentage of the investigations were conducted globally, evaluating this approach has always been challenging. In 1970, a revolutionary technique for collecting data in computer-aided design (CAD) and Revit formats was done. The result shows that we may create models using this data, but we cannot locate a plan or a 3D model in the previous structure. As a result, we must examine both internal and exterior structures building for analysis and better understanding. This information may be utilised to have a better understanding of the structure and architectural system (Kaiser et al. 1995).

Numerous research has used urban models to study topics related to smart cities, urban management and energy saving. In 2013, Bilijecki investigated 3D urban models at many levels of detail, ranging from computer graphics to mapping. This research shows that LOD paradigms, along with CityGML, will be used for various applications. However, this approach has some fundamental limitations. For instance, because discrete surfaces and their quantity are restricted, a distinction between LODs and paradigms may exist (Biljecki et al. 2015). Also, in the other study, dubbed BIM to CIM is used to develop a digital city based on a Geographic Information System (GIS). In a small-scale project, this study comprises developing and controlling the building's physical and functional characteristics. The purpose of this research is to develop a new city model for managing and building urban zones (Xu et al. 2014). Additionally, Salminen and Hägglöf examined CIM to determine the impact of CIM's distinctive capabilities on urban management in 2015. Consequently, CIM is used as a viable alternative to developing masterplan in municipalities. In other words, by the use of CIM, procedures will improve, and CIM will become a critical instrument for planning and assisting municipal work operations. CIM enables policymakers to create projections that may be utilised to plan and govern the city (Salminen and Hägglöf 2015).

In 2016, Emine et al. conducted that the challenge for urban planning in the past was producing practical information, but nowadays, the challenge of urban planning is big data and planning based on this data. This article solves this problem by using CIM in Northumbria, England. This research is classified into four key issues: data accessibility, accuracy, integration and simulation. Also, this paper cause improves the modelling and imagination of the urban planning field. In conclusion, information production and modelling may help urban planners compete more effectively in the city's public relations market. However, caution should be used in its application since statistics alone cannot ensure the growth of a sustainable urban future (Thompson et al. 2016).

Role of Digital Twins, CIM in the Simulation of Energy in Superblocks

The IoT focused on facilitating connectivity between all objects, whether physical or virtual. The most current and accurate models of a building are preserved in shared central databases throughout the design and construction phases of a project, as well as post-construction. GIS-based systems for city monitoring and management need the synthesis of data from a variety of sources, including BIMs, city models and sensors (Isikdag 2015). The best data that can be used for modelling the city is LiDAR point clouds. Recent advances in remote sensing technology have produced precise, dense and affordable city-scale LiDAR point clouds, which may be used to represent city objects (e.g. buildings, roads and autos) for the creation of digital twin cities (Xue et al. 2020). Using LiDAR for EUBM because of the limitation of the model based on point cloud is not suitable. That is why we should develop a city based on the mesh model for analysing energy consumption.

Conzen divides urban form into three components: the ground plan (streets, plans and building blocks), the building ground and fabric and the building use. In urban design, on the other hand, Rossi typology as a physical shape represents people's lifestyles. In retrospect, Rossi's followers believe that while building a city, the urban design must always be considered. This is currently a reality in several European city centres. People's ever-changing lives have been handled suitably within unchanging urban typologies. In other words, while the physical structure of the city remains constant, the design upon which it is built does (Shi et al. 2017). As a result, the study topic is to examine the design of urban blocks using a straightforward morphological technique, with the objective of generating a varied variety of human contexts that will be generally consistent, diversified and capable of reflecting urban design principles (Duany and Talen 2002).

Historically, urban planners struggle to provide useful and timely data. However, urban planners are finding problems changing urban systems through the use of technology-based feature management. As a consequence, BIM may be used to produce CityGML and Sketchup models. This program may be used to simulate urban energy consumption using data from web visualisation (Jusuf et al. 2017). Additionally, the Energy Integrated Support System (EnerISS) may be used to model an integrated urban landscape and visualise data to assist in decision-making. The modelling of building for analysing energies includes building polygons, textures for categorised land cover forms and 3D metropolitan landscapes (Yeo and Yee 2016). Numerous scholars have used BIM and GIS to map cities in various contexts. With the BIM-CIM approach, the user may directly control and manage the city by the process of linking and integrating data. The importance of policymaking based on BIM-GIM use cases, such as smart city services and city integration models, is growing. Additionally, the chance of not acquiring the essential target information for the execution of the use cases or of performing the incorrect services due to noise can be lowered (Kang 2018). GIS is frequently used to design and manage the built environment in cities. Isikdag's et al. research focuses on the development of strategies and procedures for converting an industry-standard BIM to a GIS environment in order to give a greater degree of building-related information collection in a GIS environment. The purpose of this research is to examine how to utilise a GIS to construct an IFC model (Isikdag et al. 2004).

The European Council has endorsed a binding EU target member nations joined the Kyoto Protocol, which requires European countries to pass legislation that cuts greenhouse gas emissions by at least 40% by 2030 when compared to 1990 (Bayón-Cueli et al. 2020). In recent years, owing to a heightened awareness of climate change, there has been a heightened need for research into urban energy conservation. The energy needs for buildings in the household and non-domestic sectors surpass those for transportation and industrial activities, according to statistics from the United Kingdom. Studying and simulating the behaviour of buildings are the first stage in enhancing their energy efficiency. In recent years, several energy models and methodologies have been created for this aim. However, these models often follow the viewpoint of the building designer: they tend to see structures as self-defined entities, ignoring the significance of urban-scale events. Specifically, the influence of urban geometry on energy usage is currently understudied and contentious (Ratti et al. 2005).

A city model is necessary in order to assess heat and energy. Alhamwi et al.'s energy models aided in the strategic development of municipal energy systems by providing scientific guidance. For energy policy guidance, transparency of the tools and models used, as well as their accompanying input datasets, which are not always open source, is necessary. The purpose of this study was to simulate metropolitan energy demands, especially electricity use. This study found that a certain combination of renewable energy sources may be used to generate urban energy (Alhamwi et al. 2018). Although the previous study revealed a correlation between urban morphology and energy use, policymakers and urban planners disregarded the association between the two elements due to the complexity (Ratti et al. 2005). Numerous types of the study, such as Table 32.1, indicate that digital twins, CIM, UEBM and other approaches may be valuable and practical. Additionally, by integrating this idea across neighbourhoods, superblocks and urban blocks, CIM and digital twins are established, enabling more effective city management.

Research Methodology

The study examined the morphology of urban form and its relationship to urban energy use. Due to the scarcity of data on UEBM, this information is purely comparative. This study is comparable to that of the Center for Land Use and Form Studies at the University of Cambridge, which began in the 1960s (Martin et al. 1972). This research will examine urban energy for urban superblocks, including power, cooling and heating. During the initial phase of urban planning, urban planners examine mass urban blocks with the lowest LOD in a variety of forms (Jacoby 2016; Vidmar 2013; Akin and Moustapha 2004). Shakibamanesh and Veisi conducted research on the impact of urban blocks on various types of energy, concluding that various characteristics of urban blocks affect solar radiation absorption and that the courtyard urban block type performs better in terms of energy consumption than other types of urban blocks (Shakibamanesh and Veisi 2021b; Veisi and Shakibamanesh 2022).

The research process is divided into three stages, including archetype design and modification, evaluation and prediction and selection. The entire sequence of these three phases is detailed below and illustrated in Fig. 32.1. The first part examines a case study in which five standard types of urban superblocks are thoroughly modelled using Qgis and Revit. Design variables have been substantially changed and developed for each of these six categories to the point that this component, named archetype design, provides a limited number of design choices for examination in an exploration space. The second stage begins with sampling to prepare the dataset for detection of the design space (DS). Six examples are taken from the archetype design output and entered into the dataset production process using the Qgis program

Table 32.1 Research background

Source	Subject	Objective	Method	Tools
Loibl et al. (2021)	Effects of densification on urban microclimate	The impacts of climate change are especially tangible in dense urban areas	To assess impacts of densification on urban climate	Grasshopper Ladybug + Honeybee
Agugiaro et al. (2020)	The city of tomorrow from…the data of today	To estimate the average size in existing urban areas from available open data	Designing parameters for new urban development projects	QGIS + Rhino + Grasshopper +
Groppi et al. (2018)	Buildings energy consumption	Analysing heat, electricity, consumption	Using GIS method based on urban cell	GIS
Machete et al. (2018)	Analysing the influence of urban context	The impact of the urban context on buildings' solar energy potential	The 3D approach to evaluate solar access	3D GIS
Keena et al. (2018)	Sustainable urban ecologies	Understanding of the value and impact of speculative buildings towards sustainable design development	Considered energy, material and information flows as a system	Rhino + Grasshopper + Ladybug + Honeybee Clark's Crow
Tsirigoti and Bikas (2017)	Analysing the relationship between energy efficiency and urban morphology	The relation between geometry factors and energy efficiency	The heating and cooling loads are calculated	Ecotect
Morganti et al. (2017)	Urban morphology indicators for solar energy analysis	Identifying urban morphology indicators and the solar availability on façades	Comprises seven UMIs: (1) gross space index, (2) floor space index, (3) façade-to-site ratio, (4) average building height, (5) volume–area ratio, (6) building aspect ratio, (7) sky factor of building façades	Heliodon2 software

(continued)

Table 32.1 (continued)

Source	Subject	Objective	Method	Tools
Ramesh (2018)	Urban Energy Information Modelling	A framework to quantify the thermodynamic between the natural and the built environments	The generation and simulation of the urban microclimate	ENVI-met
Amado et al. (2017)	A cellular approach to net-zero energy cities	Urban planning driver to optimise and manage energy	Geographical urban units delimitation	Esri ArcGIS + Rhinoceros + Diva
Cerezo Davila (2017)	Building archetype calibration	Effective urban Building Energy Modelling	UBEM simulation infrastructure	ArcGIS
Mert and Saygın (2016)	Energy-efficient building block design: an exergy perspective	The suitability of the exergy analysis on the built environment	Data handling	-
Amado et al. (2016)	Energy-efficient city	A model for urban planning	A theoretical model and its practical application which relates energy consumption and solar energy	ArcGIS
Dogan (2015)	Automated building energy model	Provided a streamlined workflow: single and multi-building energy evaluation	Building performance simulation engines	Parametric scripting environment Grasshopper EnergyPlus TRNSYS
Lin (2013)	Investigating reducing building energy use at the urban scale	Understanding the energy consumption of buildings in a city	Analysing the energy performance: The top-down approach regards building units The bottom-up method in regional and national levels	Sketch up
Kanters and Horvat (2012)	Solar energy as a design parameter in urban planning	The impact of the geometry form on the potential of solar energy	Parametric design	Ecotect and DIVA

and the OSM database. This method is shown in further detail in Fig. 32.1's model generation subprocess diagram, which receives six samples as a 2D model and transforms the 2D model to a 3D model using Revit throughout the integrated simulation process. After completing the model generation section, the output, which is currently prepared as a complete 3D model, is entered into the energy analysing process. In this section, six 3D models (urban blocks of tower, courtyard, hybrid, perimeter, exist and slab) are created, and a comparison is made among these six by ASHRAE 90.1. After analysing, testing and assessing the models, courtyard is chosen as the best one for this research. Finally, this BIM and GIS model functions as a building multi-performance simulation fast engine, capable of predicting the unlimited number of design possibilities accessible in this project's design space. In the third stage, this urban block multi-performance simulation engine is integrated with Revit to provide the most optimum solutions feasible for the six key urban superblock categories. The next step is to identify the optimal solution based on the designer's priorities or project requirements. Each phase is detailed in detail, along with the actual instruments utilised throughout each phase's implementation.

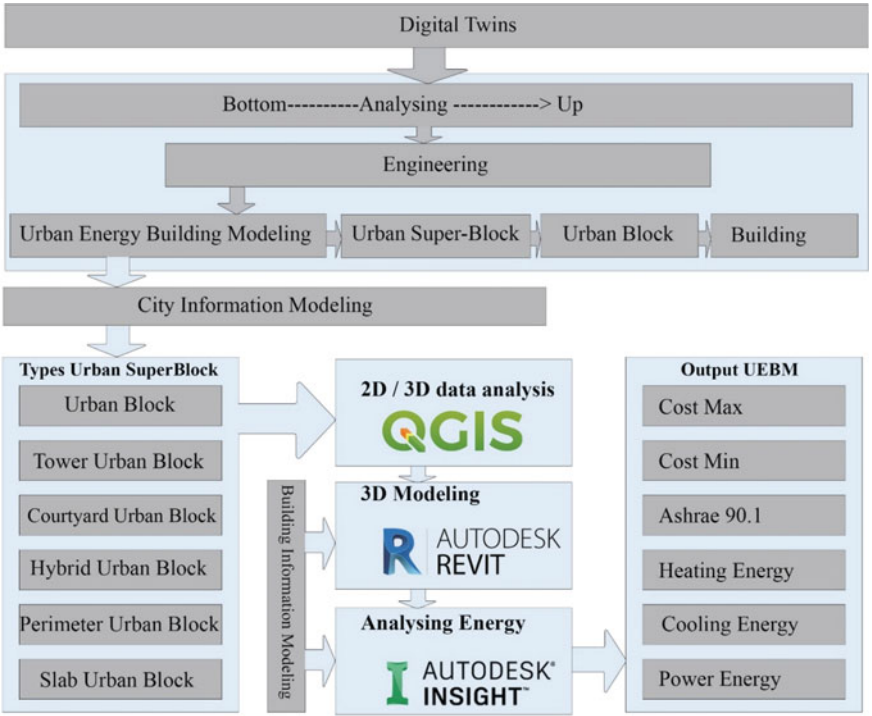

Fig. 32.1 Research framework. This framework is structured in three main phases, and all of them perform integratively in total

Step 1: Generative 2D and 3D Model

Typically, urban blocks are conceived and constructed using one of two approaches: planned and unplanned (organic) configurations. This research focused on planned configuration. An urban block is separated into numerous types in the planned configuration, including pavilions, slabs, terraces, terrace courts, pavilion courts and courts (Taleghani et al. 2013). According to Zhang et al.'s, study urban blocks are classified into six types: tower, slab, courtyard, hybrid and perimeter (Zhang et al. 2019). The six types of models produced in this research were based on metropolitan superblocks. As a result, tower typology is made up of independent tower blocks that are arranged in the form of a square or cross. Furthermore, the slab courtyard typology is made up of blocks with a completely enclosed courtyard in the centre that is uniform. In addition, hybrid typology is made up of a combination of courtyard blocks and slabs without a totally enclosed courtyard, while perimeter typology is made up of L blocks of varying heights placed around the site's perimeter.

Qgis and Revit software were used to create the geometry of these six kinds of urban superblocks (BIM and GIS software). The DVs defined by OSM data are the ultimate shapers of each of these urban superblock geometries. The range of each DV is determined by the designer's expertise. The starting value of each DV is set to a midpoint in the range, and the base case (or reference model) is then constructed. There are six varieties of urban superblocks, as seen in figure. The researchers' experiences in determining the most significant categories of urban blocks and superblocks are shown Table 32.1, which is obtained from a literature study. According to this statistic, this research, which focuses on urban design and urban planning, attempted to choose USB that included a section on design aspects. Thus, the factors chosen were totally within the limits of type of superblocks, form and geometry and mass of blocks, all of which were shown to be relevant in energy studies (Table 32.4). Another critical problem in this respect was the case study's demands and requirements. It should be noted that, as seen in Tables 32.2 and 32.3, the USB variable's floor is often taken to be 4. Additionally, the material employed in this research for mass glazing and mass skylight is double pane clear for all USB types. Additional information for various types of element blocks was included in Tables 32.2 and 32.3.

Step 2: Energy Calculation

This study used the adaptive TC model to calculate the PTC in the 12 months of the year. This model was developed based on the ASHRAE 90.1 (ANSI and Standard 2010) standard and can be used as a powerful tool in the environment of the Insight360 plugin (Stine 2015). This service was introduced in November 2015 which is used to energy modelling, cooling and heat load analysis, lighting and solar analysis and based on Cloud Energy Plus services. Using this plugin has several limitations, such

Table 32.2 General conditions for loading urban blocks in Green Building Studio and Insight360

Mass model	Constructions
Mass exterior wall	Lightweight construction—low insulation
Mass interior wall	Lightweight construction—no insulation
Mass exterior wall-underground	High mass construction—typical mild climate insulation
Mass roof	Typical insulation—cool roof
Mass floor	Lightweight construction—no insulation
Mass slab	High mass construction—no insulation
Mass glazing	Double pane clear—no coating
Mass skylight	Double pane clear—no coating
Mass shade	Basic shade
Mass opening	Air
Category	*Analytic constructions*
Roof	4 in lightweight concrete (U = 1.2750 W/(m^2K))
Exterior walls	8 in lightweight concrete block (U = 0.8108 W/(m^2K))
Interior walls	Frame partition with ¾ in gypsum board (U = 1.4733 W/(m^2K))
Ceiling	8 in lightweight concrete celling (U = 1.3610 W/(m^2K))
Floors	Passive floor, no insulation, tile or vinyl (U = 2.9582 W/(m^2K))
Slabs	Un-insulation solid (U = 0.7059 W/(m^2K))
Doors	Metal (U = 3.7021 W/(m^2K))

as data output, and needs internet for analysing data. After sketching 2D USB, the DVs were imported into Revit for modelling. This model should be analysed by Insight360 and on the Green Building Studio's website.

As previously indicated, an HVAC system was examined for each month of the year based on research assumptions calculating heating energy use in kWh/m. The yearly power consumption due to daylight/artificial light, on the other hand, is approximated as'lighting' in kWh/m based on the study assumptions. In this respect, the simulation settings were designed such that the bulbs only turn on when the illuminance level of daylight in the area falls below 300 lx. Finally, the heating and lighting energy (HLE) in the study building is represented by the total of heating and lighting.

Table 32.3 Significant variable for planning urban blocks

Model name	Cost max*	Cost mean*	Cost min*	Arch 2030*	ASHRAE 90.1*	EUI max**	EUI mean**	EUI min**	Building area m^2
Hybrid	7.06	6.02	4.47	1.75	11.33	85.93	75.10	58.90	256490.10
Courtyard	6.77	5.72	4.18	1.75	11.16	83.05	72.21	56.00	273465.80
Slab	7.42	6.35	4.77	1.75	7.08	80.08	68.78	52.11	303716.10
Tower	20.02	18.34	16.15	1.97	29.54	**292.75**	**275.87**	**253.63**	289575.50
Exist	9.12	7.75	5.88	4.40	12.00	99.05	85.33	66.25	331400.00
Perimeter	6.53	5.49	3.95	1.75	11.42	63.18	52.43	36.31	246868.90

*(USD/m^2/year)
**(kWh/m^2/year)

Algorithm 1. The rules for analysing 3D USB model
1. **procedure** *Name(3D USB model)*
2. *Choose "Height USB model"*
3. *in the setting*
4. *U ← 1.27 W/(m2 K) ▷ set the material of roof of USB*
5. *U ← 0.81 W/(m2 K) ▷ set the material of EW of USB*
6. *U ← 1.4 W/(m2 K) ▷ set the material of IW of USB*
Frame partition with ¾ in gypsum board
7. *U ← 1.3 W/(m2 K) ▷ set the material of Ceiling of US*
8. *U ← 2.9 W/(m2 K) ▷ set the material of Floors USB*
Un-insulation solid
9. *U ← 0.7 W/(m2 K) ▷ set the material of Slabs USB*
Passive floor, no insulation, tile or vinyl
10. *U ← 3.7 W/(m2 K) ▷ set the material of Doors USB*
Metal
▷ set the Analytic Constructions of element of USB
11. i ← hourly indoor temperature
12. j ← dset the location
13. **end procedure**

Step 3: Case Study

The urban blocks were designed and constructed by managers and planners in 1962 to meet the demands of the city of 22-Bahman in Kermanshah, Iran. Kermanshah city is characterised as having a semi-arid and wet climate, owing to its relatively wide territory and varied hilly topography, and each district has its own climate. Although it has chilly winters and hot summers in general, its western areas have a dry climate, while the central, northern and foothills have a Mediterranean climate. The municipality of Kermanshah has split the city's map into eight districts. The 22-Bahman is situated in Kermanshah's district 1 at a latitude of 34.202 and a longitude of 47.05, at an elevation of 2291 m, as shown in Fig. 32.2.

Based on 25-year records from the Kermanshah synoptic station, the average annual sunlight hours is 2906.7 h. According to these figures, the average number of snowy days was 12.7 days, and frost days were 104 days each year, and since the residential area is utilised to HVAC for thermal comfort during this time. As a result, heating systems must be turned on. On the other side, the same locations endure hot weather from May 15 to September 1, a period of 135 days. This critical time of year may be thought of as an active cooling system for the structures. This consideration implies that best design options tend to enable the building to give

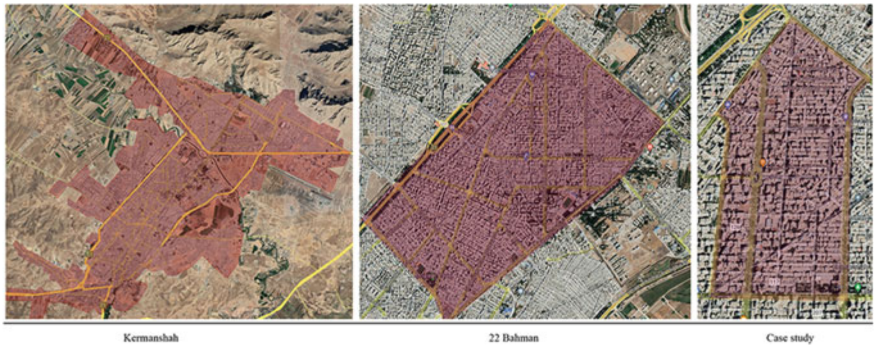

Fig. 32.2 Case study of Kermanshah

the highest PTC with an active cooling system during the warmest months of the year. It should be noted that heating in the study area is typically provided through gas resources, which is not a challenge for Iran, but cooling systems in this area are typically provided through electricity and water resources, which can be said to be relatively challenging given the conditions in Iran. As a result of the above, this research aimed to offer optimal building heating through active systems, and the design process is such that the maximum PTC is produced in the hot season of the year without the need of an active cooling system.

In this study, a highly populated 22-Bahman neighbourhood was modelled as a sample area for Kermanshah to analyse the impacts of different types of urban superblocks on energy consumption and potential adaption techniques. The example study in Fig. 32.2 looked at Kermanshah's 1st district and assessed the large-scale urban block's possible effects on cool, heat, fossil fuel and energy demand. Kermanshah is a city in Iran that is located to the west. In terms of energy consumption, this city is among the most energy-intensive. These neighbourhoods' energy requirements are critical for reducing energy consumption.

In order to define the heating system for the models, ideal air loads were selected as the HVAC system in the Insight360 settings, which can be the best choice for the early design stages, considering the cost of time in the simulation process. The occupancy and infiltration schedules were set to the same values as the default residential unit settings in the Insight360 program (these software's default settings are based on ASHRAE schedules). According to needs and standards, occupancy activities and times were deemed local, and other parameters were determined by the program using default standard information.

Results

In this study, the analytical comparative method was used to assess the influence of several types of urban superblocks on reducing energy consumption in Kermanshah's 22-Bahman area. In addition, based on the local norm of the Iran Engineering Organization, we considered a particular type of USB in the lowest LOD with 30% transparencies confronted. The blocks have been employed based on ideas of separating and integrating them, counter yard or hybrid them and other forms of urban blocks in order to achieve the best sorts of USB. The optimal form in terms of energy usage is derived after studying six kinds of urban block configurations. We will be able to figure out what forms work best in this location this way.

According to Fig. 32.3, six types of USBs in 22-Bahman neighbourhoods of Kermanshah were investigated in this study. The analysis results are shown in Fig. 32.4 according to the Green Building Studio and Insight360 sites (Stine, 2015) established by Autodesk for this program. The sole variable in this experiment is the type of block and its area, and these conditions are the same for all blocks. Three kinds of energy indicators were examined in this study: total energy, power energy and fuel energy. The original concept was thoroughly examined. The first investigation will focus on the site's current urban block, which has been uploaded and examined in accordance with the ASHRAE standard (Fig. 32.3). The present designs, as well as the anticipated analyses, are shown in Fig. 32.5:

According to Fig. 32.5, the use of fuel energy in the existing USB grew by roughly 100 W/m^{2}K between January and December. From May through August, a year's worth of energy is increased. The overall point value is greater than in January and August. This sort of urban block requires 85.3 W/m^{2}K. Numerous sources of energy are excessive per ASHRAE criteria (Fig. 32.6). The energy consumption will be raised by 59 W/m^{2}K to fulfil the ASHRAE standard. Between January and December, fuel energy climbed by around 200 k. However, between May and August, electricity energy is increased by around 50 W/m^{2}K. December and January saw an increase in total energy to roughly 4 M. The perimeter block consumes 52.4 kWh of energy each year, according to ASHRAE regulations. This value should be enhanced by at least 26.2 to meet ASHRAE standard consumption energy requirements. To summarise, municipal planners and officials should consider enacting a specific strategy to minimise energy use during the months of December and January in order

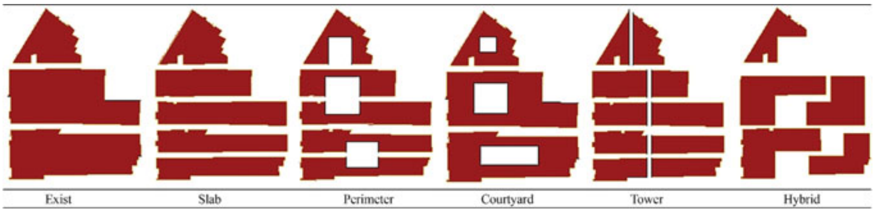

Fig. 32.3 Different shapes of USB next to each other

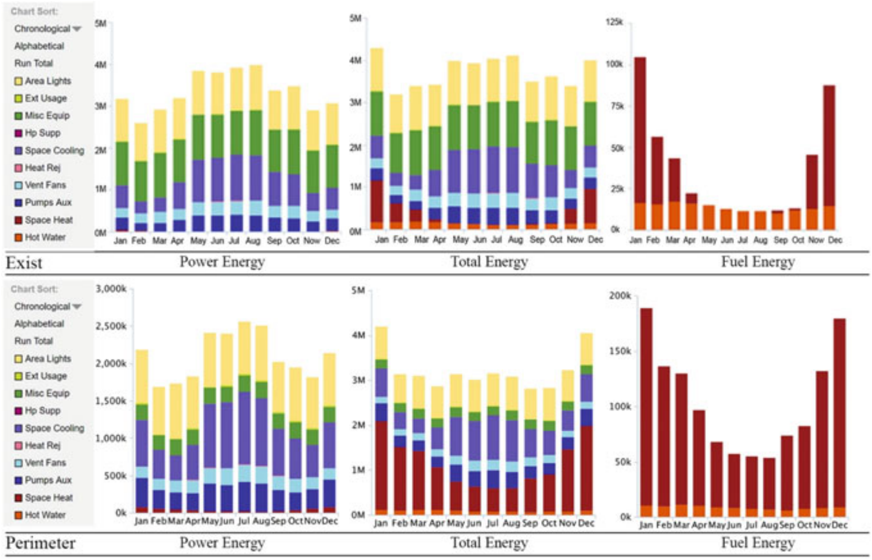

Fig. 32.4 Energy consumption for different types of an urban block in the urban block of 22-Bahman neighbourhood

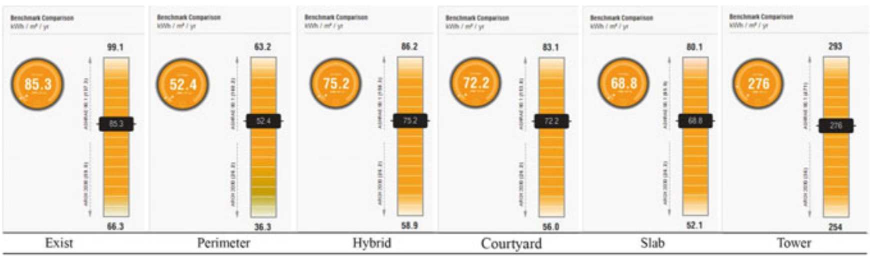

Fig. 32.5 Energy consumption for different types of the urban block based on ASHRAE standard

to save fuel. From May through August, this regulation on electrical equipment is also fairly significant.

Figure 32.7 illustrates the energy consumption of four distinct kinds of urban blocks in three distinct energy consumption categories: fuel, power and total. The first column indicates that May, June, July and August are the peak months for electrical energy use in counter-yard, hybrid, slab and tower. The last column included data on fuel energy use, with the greatest levels happening in January and December and the lowest levels occurring in May and August. According to this online research, various urban block types utilise varying amounts of energy. In December, for example, the hybrid urban block used 4 million kilowatt-hours of electricity, whereas the tower consumed 15 million kilowatt-hours. This research established a relationship between the different forms of urban blocks and energy use.

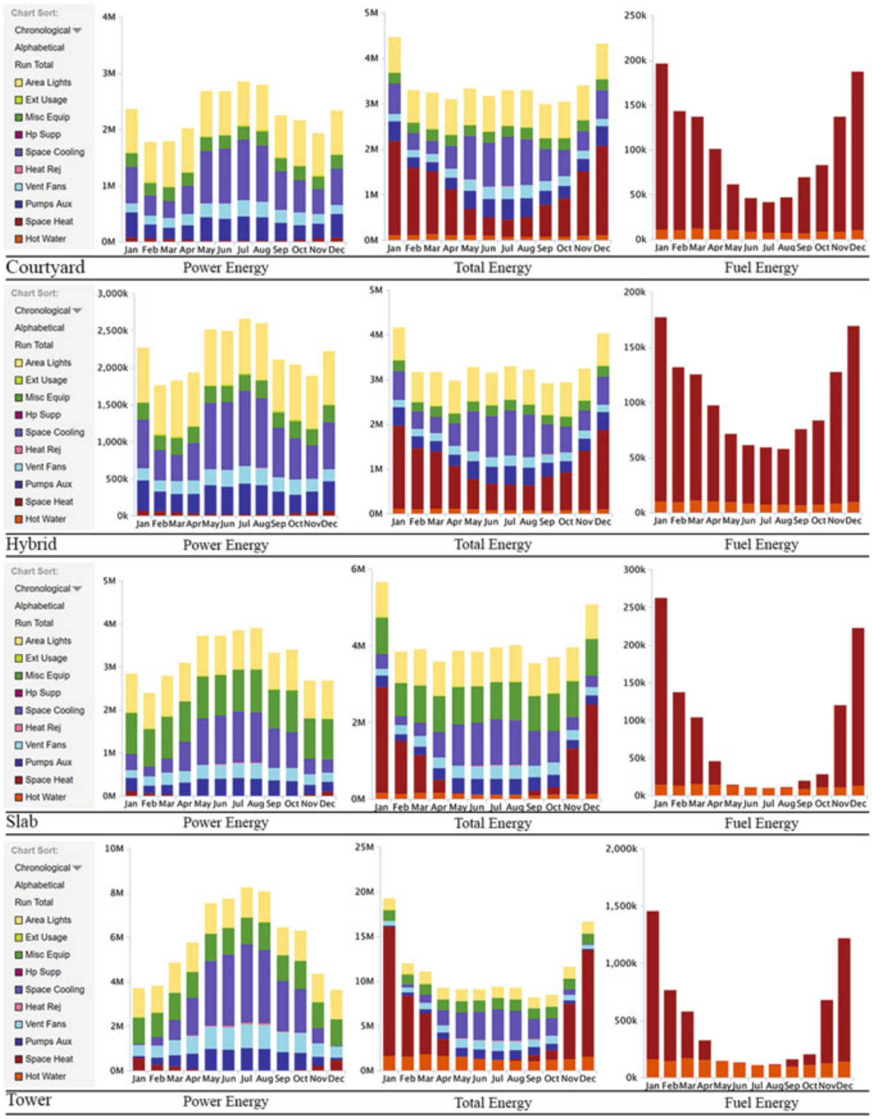

Fig. 32.6 Energy consumption for different types of an urban block in the urban block of 22-Bahman neighbourhood

In January and December, the courtyard kind of urban block consumes the most fuel energy, approximately 200 Wh/m^2/yr, while July consumes the least, around 40 Wh/m^2/yr. Data on power energy usage is collected in a variety of ways. Among May, June, July and August, the largest use of electricity energy is 3 MWh/m^2/yr, while the lowest is around 1.5 MWh/m^2/yr in February and November.

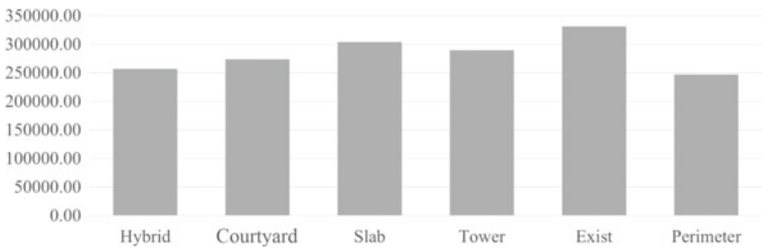

Fig. 32.7 Area of urban blocks

The monthly energy consumption of a hybrid kind of urban block is between 2500 and 2000 KWh/m^2/year, which is the ideal amount in comparison to other urban blocks.

The energy efficiency of urban slab blocks is significantly higher than that of other blocks, ranging between 250 and 5 KWh/m^2/yr. However, the electricity energy depicted in Fig. 32.7 is required in the range of 4–2.5 MWh/m^2/yr, which is a key component of this sort of super urban block's overall consumption. These sorts of tower urban blocks consume between 20 and 10 MWh/m^2/yr more energy than other blocks.

In general, simulation was used to assess the annual energy consumption of urban blocks connected to the best form of urban blocks at the district level. The greatest result connected to foul energy is the kind of exist urban blocks due to the integrated model, notably for using fuel energy in space heat about 100 kWh/m^2/yr, according to the data in the bar chart. Hybrid and perimeter urban models are the two most effusive forms of urban models.

Figure 32.8 depicts the area of various urban blocks, which has an impact on energy usage. Figures 32.8 and 32.9 show the area and EUI, respectively. On the other hand, existing urban blocks have the largest area of all urban blocks, yet their EUI is not higher than other types of urban blocks. Perimeter blocks also have a small footprint and low energy use. The measurement of EUL in the tower blocks, with a range from 293 to 254, while the area is a minimum of roughly 250,000, is a notable point in Fig. 32.9.

Table 32.3 and Fig. 32.8 reveal that EUI in all types of urban blocks ranges from 65 to 100, except for tower urban blocks, which have a EUI of around 275. Because of the connection between the face and the outside, the tower blocks, in my perspective, required substantially more energy based on ASHRAE 90.1.

The correlation is a statistical test demonstrating the relationship between variables with values ranging from −1 to 1. The number near 1 denotes a high two-factor correlation, while −1 denotes a reverse data correlation. Also, if the correlation test yields a number close to 0, this indicates that there is a weak association between variables. Table 32.4 and Fig. 32.10 indicate that cost and ASHRAE 90.1 have a good correlation of 0.97. However, there is a weak link between EUI and building area data, around 0.18, and between building area and ASHRAE 90.1 data, about 0.04.

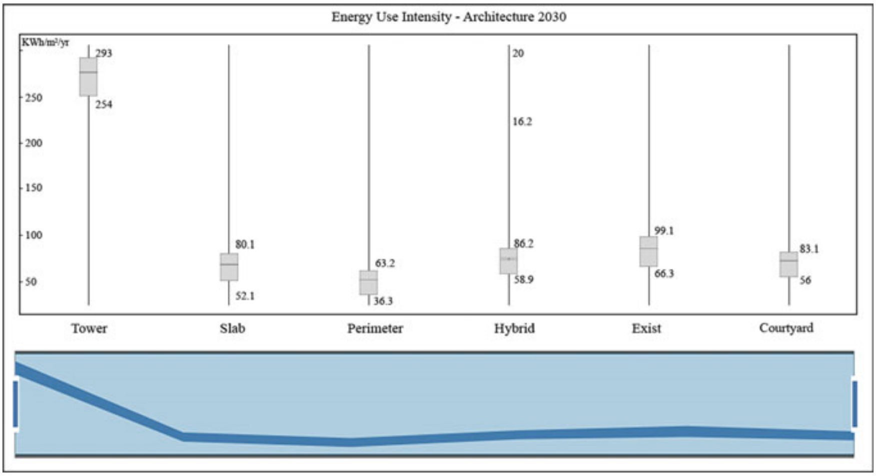

Fig. 32.8 EUI of urban blocks

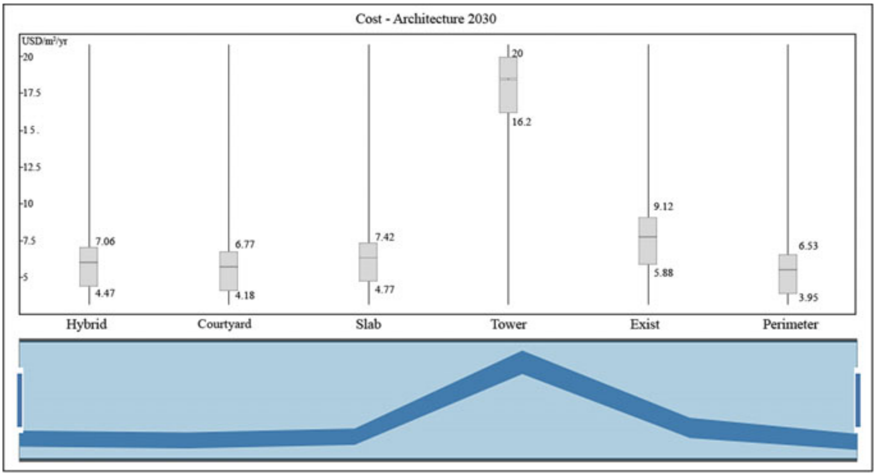

Fig. 32.9 Cost of energy consumption of urban blocks

Table 32.4 Correlation between variables

	Cost	Arch 2030	ASHRAE 90.1	EUI	Building area
Cost	1	0.03	0.97	1	0.24
Arch 2030	0.03	1	−0.03	−0.03	0.77
ASHRAE 90.1	0.97	−0.03	1	0.97	0.04
EUI	1	−0.03	0.97	1	0.18
Building area	0.24	0.77	0.04	0.18	1

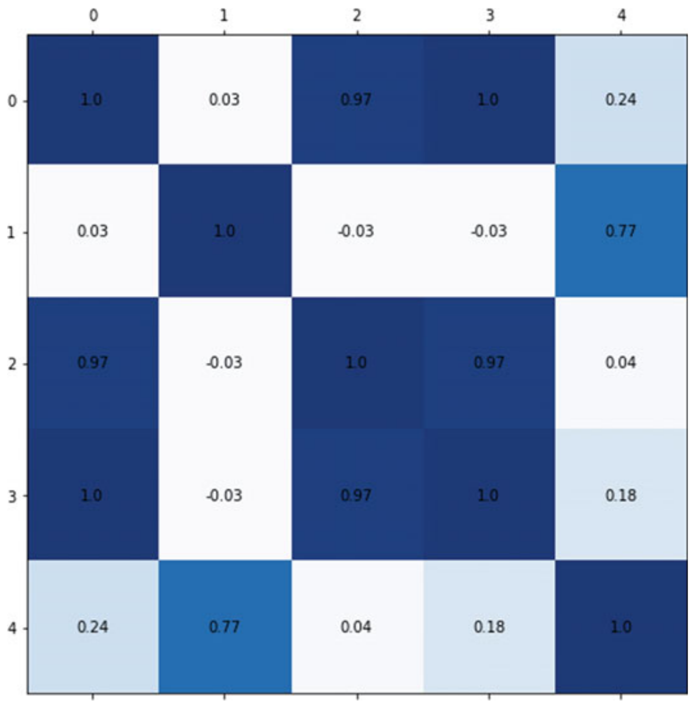

Fig. 32.10 Correlation between variables

The required monthly electric energy consumption, as well as HVAC optimisation via energy savings in different equipment, is shown in Fig. 32.11. As seen in Fig. 32.11, HVAC optimisation is only accomplished on an annual basis. As seen in this graphic, various types of urban blocks need different criteria. Figure 32.12 demonstrates that energy conservation via the use of an optimal heating system is a possible alternative, since it is difficult to attain 100% heating cover at higher densities. The electrical load efficiency of various metropolitan blocks is represented in Fig. 32.12. As seen in this graphic, monitoring efficiency may help reduce energy use.

Discussions

Significant Findings

Analysing energy consumption should be discussed for finding optimum solution in urban superblocks for reducing energy consumption in city. Because the urban superblock is the first urban feature to be built, by urban planners and urban designers.

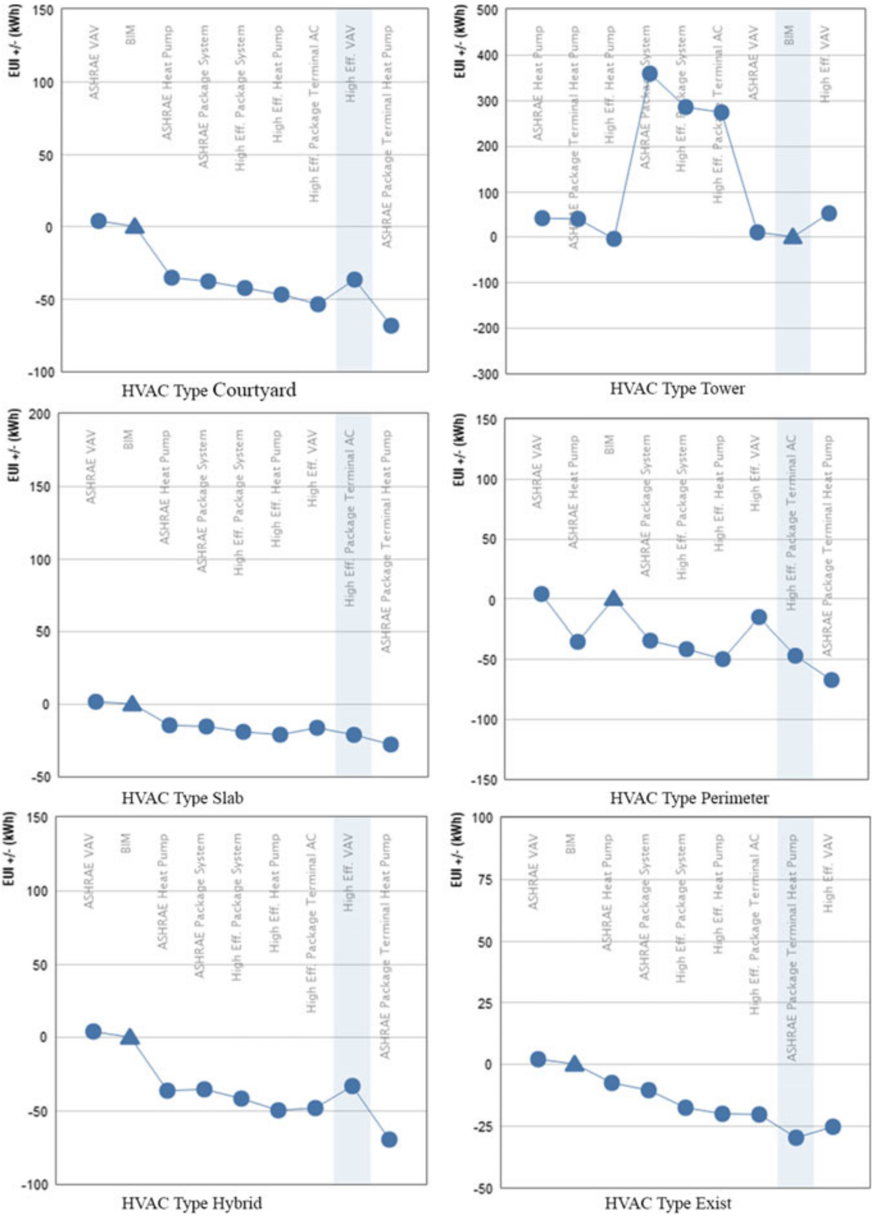

Fig. 32.11 HVAC optimisation via energy savings in different equipment

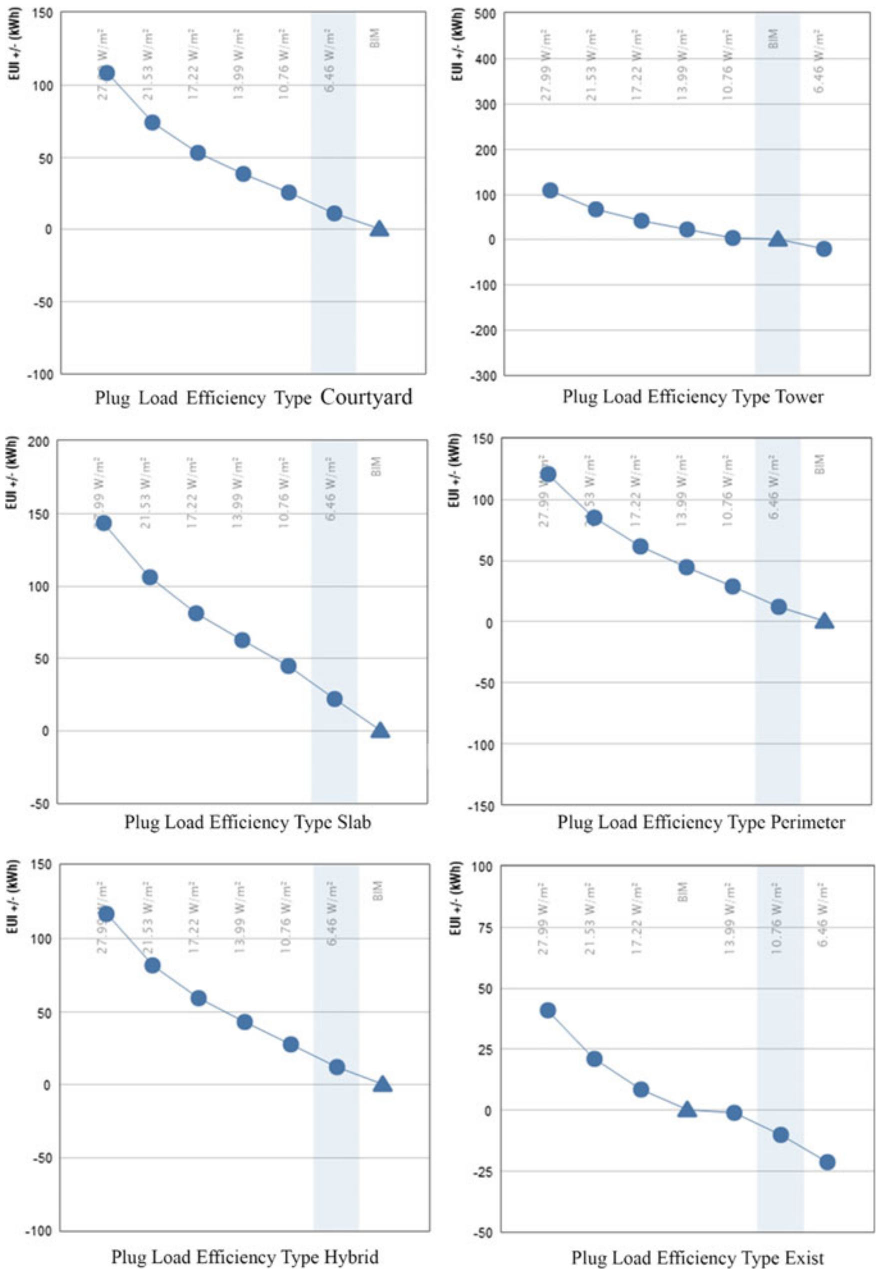

Fig. 32.12 Energy conservation via the use of an optimal heating system

Because the type of many buildings reduces the energy consumption by the interior space to a large extent. In this study, urban superblocks have been explored as an autonomous entity that is impacted by neighbouring sections. The results of this study reveal that each superblock has a varied amount of energy consumption under the impact of its component factors, including Area, and block type which is compatible with the research findings (Veisi et al. 2022; Shakibamanesh and Veisi 2021b).

The research demonstrates that various kinds of urban blocks should be chosen based on the investigated environment, location and cost of energy consumption in order to attain lowest energy consumption. In this chapter, six distinct types of urban superblocks were analysed, and according to the kind of urban superblock, each species used a distinct quantity of energy. Consequently, the surface area variable and the ASHRAE 90.1 cost standard have the highest influence on Energy Use Intensity. This is in line with current study results in the area of Energy Use Intensity in buildings and urban environments (Ghorbanian and Chehragan 2022).

The examination of six categories of superblocks demonstrates that the species of urban blocks may alter the quantity of energy consumption. As a result, urban planners and designers to effectively pick species, they must consider the kind of each species in relation to the local climate. This study is consistent with the findings of earlier studies in the area of the impacts of urban morphology type. This study aims to minimum energy consumption by using the ASHRAE 90.1 and BIM and CIM model (Morello et al. 2009; Pakzad and Salari 2018). Numerous research have been conducted on the appropriate scale for the shape of an urban block, with varying ranges of values for various kinds. However, no study has been conducted on the ideal ASHRAE model and cost function by use of CIM and BIM model for selecting best urban superblocks based on EIU; this is one of the first studies on this subject. The findings indicate that cost and ASHRAE 90.1 have good correlation with each other, and city superblock may be selected based on the ideal configuration, cost, ASHRAE 90.1 and EUI.

On the other hand, the findings of this study indicate that it is conceivable to utilise the CIM and BIM model to anticipate various types of energy consumption in different superblocks and metropolitan locations, necessitating a larger data collection comprised of climate-specific studies. Consequently, as a result of the research conducted by the researchers, the research in the aforementioned context can be expanded in terms of the species used, and more variables and patterns can be investigated in future studies, as this research is more diverse in terms of examining and implementing new methodologies (Shakibamanesh and Veisi 2021a; Veisi et al. 2022).

The Innovation

Novelty may serve as both the research topic and the research methodology in the current study. As previously stated, the major purpose of this study was to discover the most energy-efficient urban superblock type. This study analysed an alternate viewpoint based on the outcomes of prior research and divergent opinions about the most energy-efficient form of urban superblock. In order to determine the optimal limit of an urban superblock, the inverse relationship between the area of an urban block and energy consumption, the direct correlation between the ASHRAE model and cost function has been taken into account, and the research hypothesis considers the need to maintain diversity in the urban fabric in order to achieve the lowest amount of energy consumption with the smallest amount of area in various types of urban superblocks. In terms of the simultaneous use of CIM and BIM models for dataset production and development in estimating the amount of energy consumption by various superblocks in the target tissue, the research technique is both original and unique.

Conclusion and Future Work

This study highlights the importance of assessing urban blocks and energy consumption, as well as the demand and supply of building energy through integrated fuel and electrical energy. However, given the geometric complexity, it is necessary to evaluate the relationship between energy usage and the kind of urban blocks. Additionally, the approach makes use of OSM data to estimate the amount of energy used by a USB at a certain time and date and place. The suggested approach would serve as a critical reference for the annual energy usage of urban blocks, including fuel, electricity and lighting.

Because the type of urban block is often associated with a change in the degree of connection to the outside world, the need for energy consumption as a result of the type of urban block resulted in a monthly drop in energy consumption (0.20%). On the other hand, after evaluating examples in Kermanshah and determining the energy constraints of each shape, it may be considered a courtyard and perimeter kind of urban block for developing urban blocks in Kermanshah's 22-Bahman region. As previously noted, this form of central courtyard layout has been employed multiple times in this context.

The investigation's final section focuses on improving energy usage in urban areas, which results in more accurate data in various locations. As a result, this procedure has been accepted and standardised. As a result, academics can look into the subject of energy with an emphasis on BIM and CIM to tackle some issues in the initial level of design, where urban planners and policymakers lack knowledge. As a result, concerns like parametric modelling, energy efficiency, smart city regulations aimed at lowering energy consumption and how to use City Information Modelling to anticipate and design smart urban codes are topics that can aid researchers in developing this methodology.

Additional research should focus on more practical aspects of building design and construction. This might contribute to a greater understanding of the issues around building performance improvement. Thus, future research should address and propose solutions to practical and complex problems in the field of architecture through the discovery and investigation of artificial intelligence models and the use of other deep learning capabilities such as convolutional neural network (CNN), generative adversarial networks (GAN) and classification.

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